

**APPLICATION OF RESERVOIR CHARACTERIZATION AND ADVANCED TECHNOLOGY TO IMPROVE  
RECOVERY AND ECONOMICS IN A LOWER QUALITY SHALLOW SHELF SAN ANDRES RESERVOIR**

**QUARTERLY TECHNICAL REPORT**

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## **OBJECTIVES**

The Class 2 Project at West Welch was designed to demonstrate the use of advanced technologies to enhance the economics of improved oil recovery (IOR) projects in lower quality Shallow Shelf Carbonate (SSC) reservoirs, resulting in recovery of additional oil that would otherwise be left in the reservoir at project abandonment. Accurate reservoir description is critical to the effective evaluation and efficient design of IOR projects in the heterogeneous SSC reservoirs. Therefore, the majority of Budget Period 1 was devoted to reservoir characterization. Technologies being demonstrated include:

1. Advanced petrophysics
2. Three-dimensional (3-D) seismic
3. Cross-well bore tomography
4. Advanced reservoir simulation
5. Carbon dioxide (CO<sub>2</sub>) stimulation treatments
6. Hydraulic fracturing design and monitoring
7. Mobility control agents

## **SUMMARY OF TECHNICAL PROGRESS**

West Welch Unit is one of four large waterflood units in the Welch Field in the northwestern portion of Dawson County, Texas. The Welch Field was discovered in the early 1940's and produces oil under a solution gas drive mechanism from the San Andres formation at approximately 4800 ft. The field has been under waterflood for 30 years and a significant portion has been infill-drilled on 20-ac density. A 1982-86 pilot CO<sub>2</sub> injection project in the offsetting South Welch Unit yielded positive results. Recent installation of a CO<sub>2</sub> pipeline near the field allowed the phased development of a miscible CO<sub>2</sub> injection project at the South Welch Unit.

The reservoir quality at the West Welch Unit is poorer than other San Andres reservoirs due to its relative position to sea level during deposition. Because of the proximity of a CO<sub>2</sub> source and the CO<sub>2</sub> operating experience that would be available from

the South Welch Unit, West Welch Unit is an ideal location for demonstrating methods for enhancing economics of IOR projects in lower quality SSC reservoirs. This Class 2 project concentrates on the efficient design of a miscible CO<sub>2</sub> project based on detailed reservoir characterization from advanced petrophysics, 3-D seismic interpretations and cross wellbore tomography interpretations.

During the quarter, the project area was expanded to include an area where the seismic attribute mapping indicated potential for step-out locations. Progress was made on interpreting the crosswell seismic data and the CO<sub>2</sub> performance simulation was further improved. Construction of facilities required for CO<sub>2</sub> injection were completed.

### **3-D SEISMIC INTEGRATION**

The project area has been expanded south to include an area containing 14 well locations identified by seismic attribute mapping. The expansion area will add approximately 275 acres to the current project area and an estimated 700,000 barrels of additional oil reserves. The multi-variable attribute mapping technique has been used to assign reservoir properties to the seismic bin locations and to successfully pick infill locations. The 14 wells program will test the application of the seismic mapping technique<sup>1</sup> for the development of step-out locations. AFE's for five of the fourteen wells have been approved and should be drilled during the fourth quarter 1997, if land issues are resolved.

### **CROSS WELL SEISMIC**

During the third quarter of 1997, work focused on automating the process of determining the angle of arrival for reflection events for each source/receiver pair in the interwell VSP data sets. Separating the reflection event from the much more powerful direct arrival event is important because of interference by the direct arrival when imaging the zone near the well bores. When the angle is properly determined, the data can be "beamformed" to emphasize the reflection arrival and to suppress the interfering direct arrival. Since it is very time consuming to do this work "by hand" (on each trace in the data set), automating the process will result in much faster turn-around times.

Work on improving data interpretation, using well logs as a guide is ongoing. Synthetic seismic data is generated from available well logs using filters to produce a wavelet with similar frequency to the interwell VSP (vertical seismic profile) data where the dominant frequency of the wavelet is about 600 - 700 Hz. By tying the wellbore synthetics to the interwell VSP section, an interpretation can be developed for the entire span between the two wells using the interwell seismic data. Unfortunately, the cyclic stratigraphic sequences in the Welch reservoir zone, which are easily seen in the well logs and synthetics, makes tying the well log synthetics to the interwell seismic data difficult. To overcome this, the seismic data is being reprocessed to be closer to true amplitude data, where earlier sections<sup>2</sup> used gain control to enhance amplitudes for reflection processing. Variations in reflection amplitudes are then used to resolve the problems in

regions where thinning, thickening, or terminations can lead to uncertainty in the interpretation.

Examples are included of a portion of two lines showing the sensitivity of the section to reflection amplitude. Figure 1 is a section of one line from the North pattern (DOE 1) and Fig 2 is from one line in the South pattern (DOE 12). Trace spacing in each case is 1 ft and the vertical span of the "live" data trace is 240 feet (4760 feet to 5000 feet from ground level at the source well). A portion of dead trace or zero amplitude was included above the reservoir zone to aid in locating the traces laterally. Amplitudes are uniformly scaled to clearly show the variation in reflection amplitude across the line. Several interesting terminations can be seen in the sections of the data which are included.

## **NUMERICAL SIMULATION**

During the third quarter, modifications were made to the performance history to incorporate the shut-in period for injection wells as workovers were performed to prepare the wells for CO<sub>2</sub> injection. The resulting drop in reservoir pressure is expected to increase CO<sub>2</sub> injection rates during the initial injection period. The model results obtained after including the shut-in period, show the increased injection will result in a quicker CO<sub>2</sub> response than previously forecasted. Figure 3 shows the comparison of the shut-in response to the previous response which did not incorporate the shut-in results and lower injection pressure.

## **AREA PREPARATION AND CONSTRUCTION**

The following are the key items that have been accomplished during the third quarter of 1997 for the facilities engineering portion of the West Welch DOE Project:

- Mechanical construction package was awarded and contractor moved on-to site on 7/9/97.
- Mobil made the hot tap into the Este CO<sub>2</sub> supply line.
- All metering and distribution piping was pressure tested on 9/16-9/17/97.
- Construction was "mechanically completed" on 9/20/97 with CO<sub>2</sub> injection to commence on 10/2/97.

Fabrication of the Mobil and OXY CO<sub>2</sub> supply piping and metering areas were completed during the third quarter of 1997. Instrumentation and control systems were also installed and functionally tested. All piping was nitrogen pressure tested by the end of the reporting period.

Fabrication of the OXY CO<sub>2</sub> distribution system and well head automation instruments and controls were completed during this reporting period. A total of fifteen (15) well connections were fabricated and fourteen (14) were installed. Each injection well assembly is comprised of a line blind (for changing to and from water and CO<sub>2</sub> injection) a line strainer turbine meter and manual choke assembly. Where the piping could be

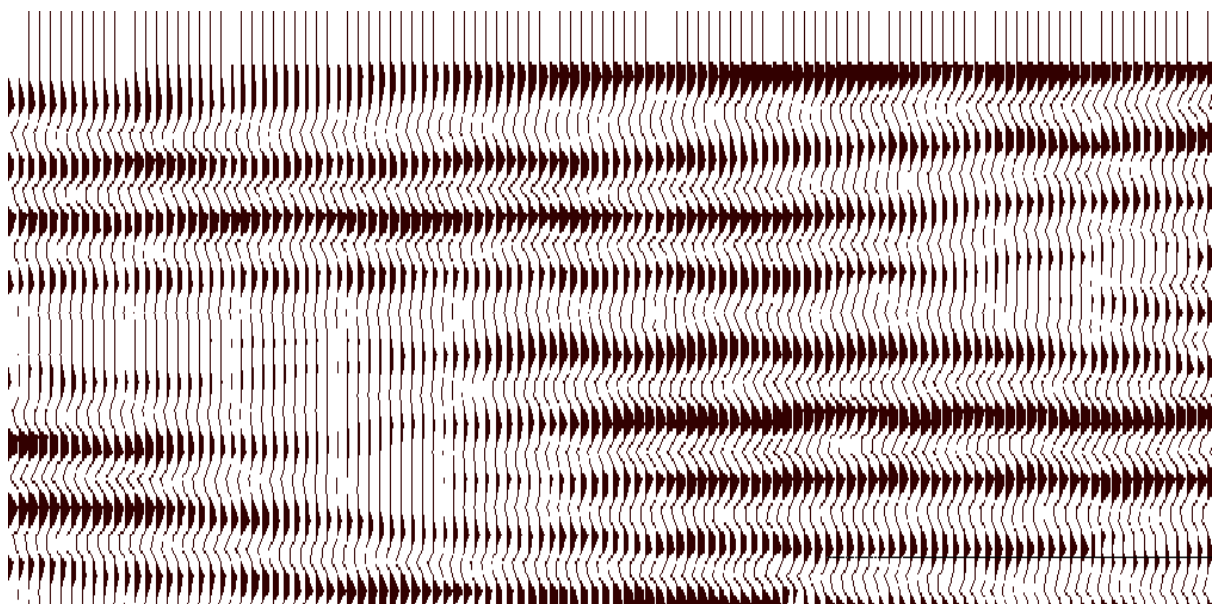
exposed to water, stainless steel was used instead of carbon steel. Additionally, supply meter locations use A333-Grade 3 or 6 piping due to the low temperatures expected during blowdown and depressurization.

## **TECHNOLOGY TRANSFER**

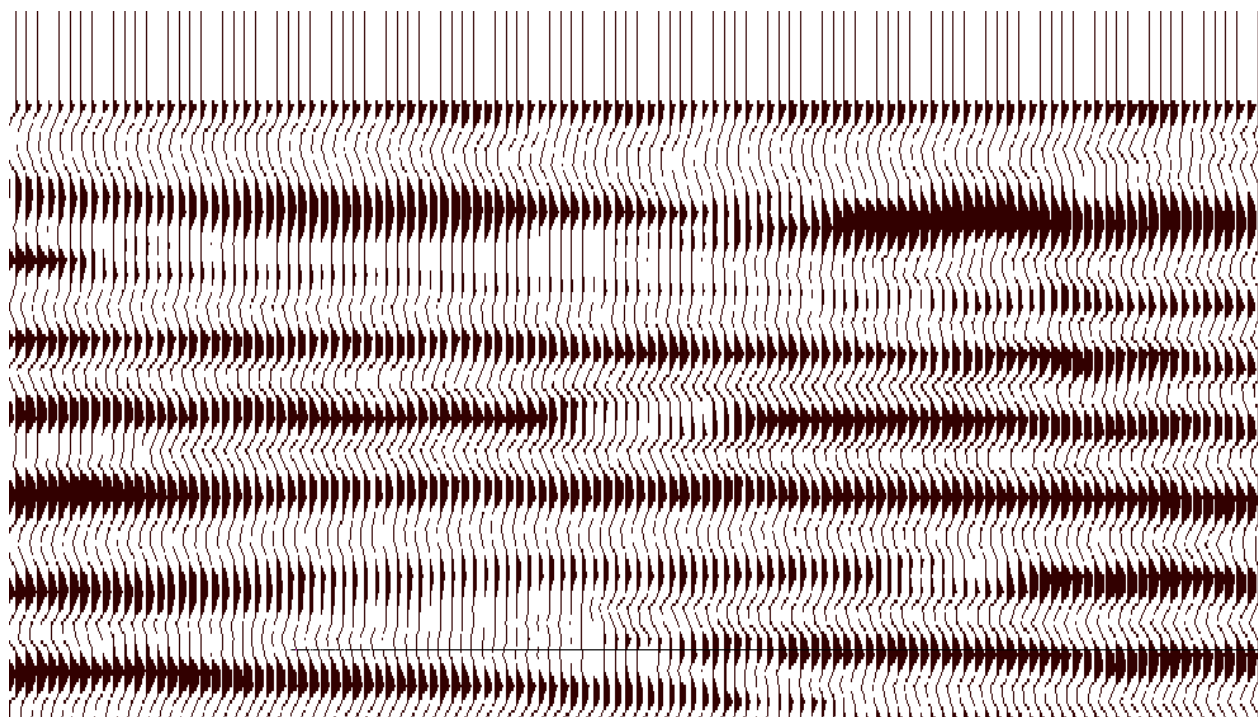
There were no technology transfer activities during this quarter.

## **REFERENCES**

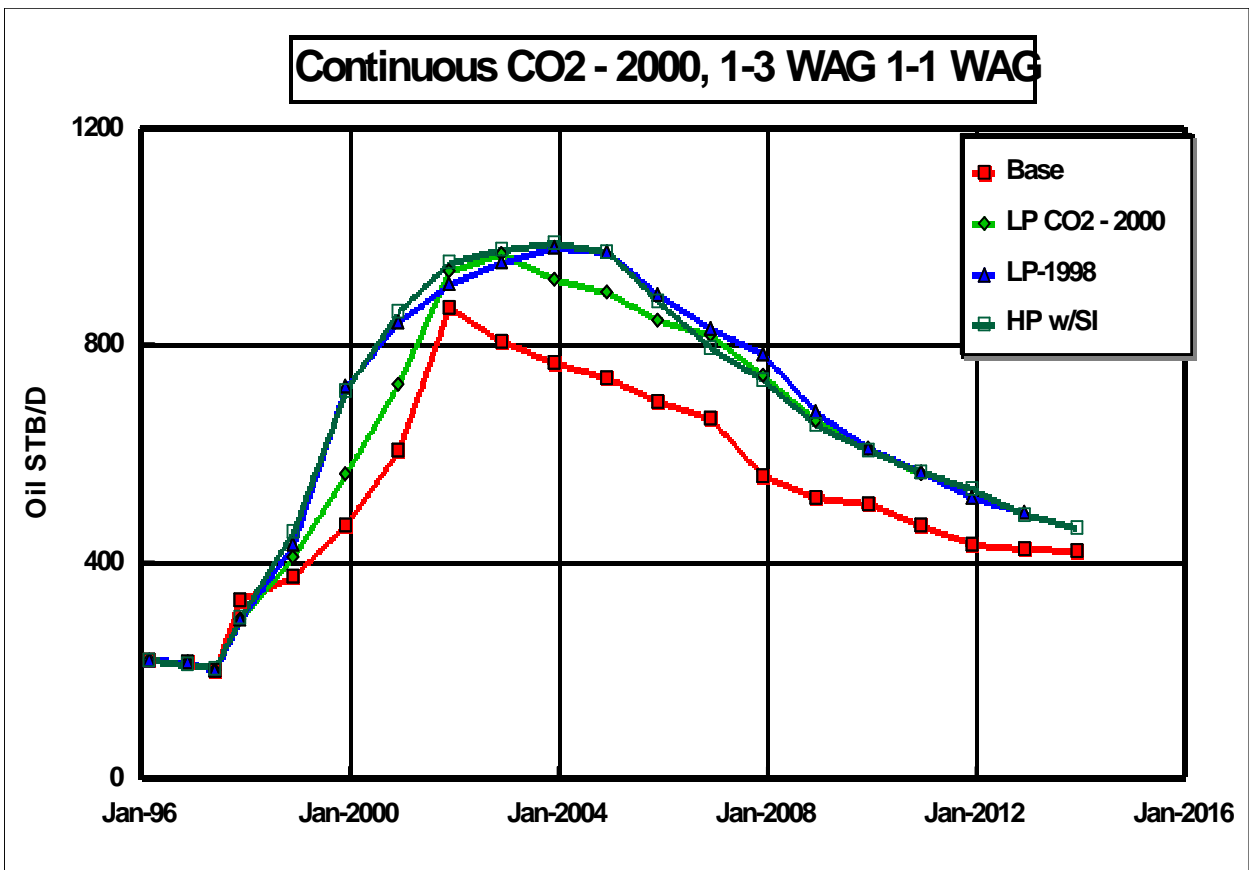
1. Watts, G.P., Hinterlong, G.D. etal, "Seismic Estimate of Porosity in the Permian San Andres Carbonate Reservoir, Welch Field, Dawson County, Texas," March 1996 Proceedings: Oklahoma Geological Society Workshop on Platform Carbonates of the Southern Midcontinent.
2. A. R. Taylor, and G. D. Hinterlong, etal, Application of Reservoir Characterization and Advanced Technology to Improve Recovery and Economics in a Lower Quality Shallow Shelf Carbonate Reservoir, DOE contract No. DE-FC22-94BC14990, Quarterly Report, January 1 - March 31, 1997.



**Figure 1** Portion of line 1 from the 7916 to the 3206.



**Figure 2** Portion of line 12 from the 4852 to the 4809.



**Figure 3** Forecasted oil production from CO2 injection.